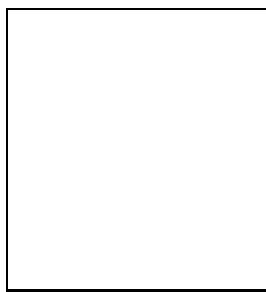


NON-SUSY SEARCHES AT THE TEVATRON

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As the integrated luminosity of Run II at the Tevatron increases, the sensitivity to new physics is approaching and in some cases surpassing that previously attained in Run I. Presented below are a selection of new results from searches for physics beyond the Standard Model at the CDF and DØ experiments.

1 Introduction

CDF and DØ continue to search for physics beyond the Standard Model at the upgraded Tevatron in Run II. The increase in centre-of-mass energy to 1.96 TeV is of particular importance for searches for high-mass objects where significant increases in production cross-section are expected. Results from a sample of analyses from both experiments are presented here, utilising between 40 pb^{-1} and 75 pb^{-1} .

2 Leptoquark searches

Both CDF and DØ are conducting searches for first and second generation leptoquark pair production, assuming no cross generational couplings and a 100% branching fraction to electron or muon plus quark. This process gives rise to an experimental signature of two leptons plus two jets and no missing transverse energy with a dominant background of $\gamma^*/Z \rightarrow ll + 2 \text{ jets}$. Presented here are results from the first generation search at CDF and the second generation search at DØ. For the first generation search events are used with two central electrons with transverse energy $E_T > 25 \text{ GeV}$ and two jets where the leading jet has $E_T > 30 \text{ GeV}$ and the next highest E_T jet has $E_T > 15 \text{ GeV}$. The invariant mass of the dielectron pair is required to be outside the range $76 \text{ GeV} < M_{ee} < 110 \text{ GeV}$. CDF observes no excess of events in 72 pb^{-1} and sets a limit on the leptoquark mass of $M_{LQ} > 230 \text{ GeV}$ at 95% confidence level which compares

favourably with the Run I limit of 213 GeV¹. The DØ limit on this channel from Run I was 225 GeV². DØ require events to have two opposite signed muons above 15 GeV with two jets above 20 GeV and a dimuon mass $M_{\mu\mu} > 110$ GeV. Utilizing around 40 pb⁻¹ of available data no signal events are observed and a mass limit is set at $M_{LQ} > 157$ GeV.

3 Searches for high-mass objects

3.1 Large extra dimensions

DØ searches for large extra dimensions, assuming the Standard Model particles are confined to a 3-brane with gravity propagating in the extra dimensions. This gives rise to a signature of an excess of high mass dilepton and diphoton events from the couplings to Kaluza-Klein (KK) gravitons. The contribution of the gravitons can be characterised by the parameter η_G in equation 1 where M is the dilepton or diphoton invariant mass, θ^* is the scattering angle in the dilepton or diphoton rest frame and f_{SM} , f_{KK} and f_{inter} represent the Standard Model, KK-graviton and interference terms in the cross section respectively.

$$\frac{d^2\sigma}{dM \cos \theta^*} = f_{SM} + f_{\text{inter}}\eta_G + f_{KK}\eta_G^2 \quad (1)$$

Events are selected in the dimuon channel by requiring two muons matched to central tracks with a transverse momentum $p_T > 15$ GeV and a dimuon mass $M_{\mu\mu} > 40$ GeV. The dielectron and diphoton channels are combined by not requiring a matched track to reconstructed electromagnetic (EM) objects in the calorimeter. The event selection requires two EM objects with $E_T > 25$ GeV and the missing $E_T < 25$ GeV. Backgrounds are estimated using fast Monte-Carlo for dilepton and diphoton production with instrumental and reconstruction fake rates being estimated from the data. Fits to data and background in the $(M, |\cos \theta^*|)$ plane show no excess of events. This can be used to set an upper limit on η_G which translates into a lower limit on the fundamental Planck scale. Results for different formalisms^{6,7,8} are shown in table 1. The limit using the di-EM channel approaches the DØ Run I result while the dimuon analysis was not performed in Run I and so is a new limit.

Table 1: Lower limits on the fundamental Planck Scale in TeV

| Formalism | GRW | HLZ, n=2 | HLZ, n=7 | Hewett, $\lambda = +1$ |
|-----------|------|----------|----------|------------------------|
| Di-EM | 1.12 | 1.16 | 0.89 | 1.00 |
| dimuon | 0.79 | 0.68 | 0.63 | 0.71 |

3.2 Randall-Sundrum Gravitons

Looking at dilepton events, CDF searches for an excess of high mass objects above the Standard Model backgrounds arising from the production of excited RS-gravitons in 5 dimensions. No excess is observed and so a region is excluded at 95% confidence level in the plane of the free parameters: graviton mass M_G and coupling k/M_{PL} as shown in figure 1. These results are competitive with those from LEP.

3.3 Z' to dilepton

CDF and DØ look for Z' production in the $qq \rightarrow Z' \rightarrow e^+e^-$ channel with CDF performing an additional search in the dimuon channel. In the dielectron channel CDF requires two electrons to be well reconstructed with $E_T > 25$ GeV where at least one of the electrons must be in the central region and the event missing $E_T/\Sigma E_T < 2.5$. DØ selects events with two electrons each having $E_T > 25$ GeV. For the dimuon channel events are selected with two muons, each

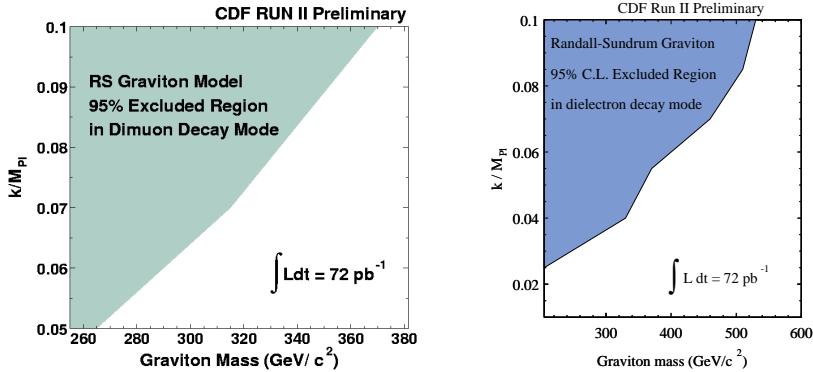


Figure 1: Randall-Sundrum graviton exclusion regions in the dimuon and dielectron decay modes

with $p_T > 20$ GeV. Neither experiment observes an excess of events above the Standard Model backgrounds. In the dielectron channel DØ sets a limit, using 50 pb^{-1} , of $M_{Z'} > 620$ GeV which approaches the Run I result of $M_{Z'} > 670$ GeV³. CDF has set limits on the Z' mass at $M_{Z'} > 650$ GeV and $M_{Z'} > 455$ GeV for the dielectron and dimuon channels respectively. This can be compared with a combined dilepton Run I result of $M_{Z'} > 690$ GeV⁴.

4 Signature based searches

In addition to carrying out model specific analyses, both experiments also use a model independant signature based approach.

4.1 dijet mass spectrum

Using their entire inclusive jet sample (75 pb^{-1}) CDF select the two highest E_T jets in each event with $|\eta| < 2$ and $|\tanh \Delta\eta/2| < \frac{2}{3}$, where η is pseudo-rapidity and $\Delta\eta$ is the difference in η for the two jets. A simple parameterisation of the Standard Model background is fitted to the dijet invariant mass spectrum to look for *bumps* comparable with the mass resolution. No significant excess is observed beyond the Standard Model background. This allows limits to be set on the production of a variety of new particles, summarised in table 2 together with the Run I results⁵.

Table 2: Excluded mass limits in GeV for new particles decaying to dijets

| Particle | RunI result | Run II limits |
|-------------------------|-----------------|------------------|
| axigluons | $200 < M < 980$ | $200 < M < 1130$ |
| excited quarks | $200 < M < 570$ | $200 < M < 760$ |
| | $580 < M < 760$ | |
| colour octet technirhos | $260 < M < 640$ | $260 < M < 480$ |
| E6 diquarks | $280 < M < 420$ | $290 < M < 420$ |
| W' | $300 < M < 420$ | $300 < M < 410$ |

4.2 $e\mu$ final state analysis

The very low Standard Model backgrounds allow a model independant approach for this analysis at DØ. Events are selected with at least one electron and at least one muon both with $p_T > 15$ GeV and with no reconstructed jets. The main physics backgrounds come from $Z \rightarrow \tau\tau$ at low missing $E_T < 25$ GeV with WW and $t\bar{t}$ dominating for higher missing E_T . The physics backgrounds are estimated from simulation with the fake rates being extracted from the data.

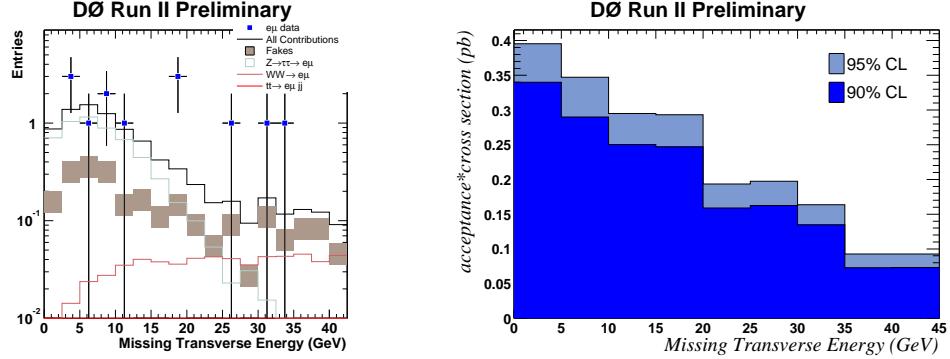


Figure 2: $e\mu$ final state data and expected backgrounds and the resulting limit on acceptance \times cross section as a function of missing transverse energy

The left panel of figure 2 shows good agreement between data and backgrounds for 33pb^{-1} . This sets 95% confidence limits on the acceptance \times cross section for new physics as shown in the right panel of figure 2.

4.3 Charged massive particles

The upgraded CDF detector in Run II includes a new Time of Flight (TOF) detector which provides a better particle identification than dE/dx for particles with higher $\beta\gamma$. Tracks with a long time of flight are selected from events firing high p_T muon triggers with $p_T > 40$ GeV to ensure full tracking efficiency. A reference time, t_0 , is established by looking at tracks with low $p_T < 20$ GeV. Events are then selected which contain a track with $TOF - t_0 > 2.5$ ns. 7 events are observed in 53 pb^{-1} of data with the background estimated from tracks in the range $20 < p_T < 40$ GeV to be $2.9 \pm 0.7(\text{stat}) \pm 3.1(\text{sys})$ events. This can be interpreted in the context of stable stop production to give a limit on the stop mass of $M_{stop} > 107$ GeV at 95% confidence level.

5 Conclusions

CDF and DØ continue to actively pursue searches for exotic new phenomena. Although no new particles or physics have been discovered in Run II, the discovery potential rises as the integrated luminosity accumulates. Results are now approaching and improving on Run I and with the improved reach of the upgraded detectors and accelerator a new signal could be waiting to be discovered.

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